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WOOD – POLYSTYRENE COMPOSITES IN THE BIOLOGICAL DURABILITY TESTS*

Kazimierz Lutomski

Chemical Wood Technology Institute
Chair of Wood Protection and Conservation
Agricultural University Poznań

Brich and alder wood containing about 75% of polystyrene has been tested in laboratory conditions on the durability against fungi causing brown, white and soft rot and also on the moulds occurence. There are also presented 14 years lasting investigations made in natural conditions in contact with the soil on the durability of composites obtained from pine, beech and alder wood containing polystyrene in amounts above 100%.

INTRODUCTION

Joining of the wood with some synthetic resins allows to obtain materials having in them many favourable properties of both constituents. New composits however need through investigations, in aim to determine possibilities and directions of use. Due to the high durability on the water action of the improved wood with the use of synthetic resins [2, 3, 17], it as it seems, to be specially predisposed for the use in conditions of highly moist environment. But it is known, that the high moisture content of environment, and substrate at proper temperature is favourable for the development of various microorganisms. In such conditions occurs among others development of various fungi causing not only decay of wood but also of many other substances and usable materials in that series of synthetic plastics [26].

In connection with that from long time in The Chair of Preservation and Wood Conservation of the Institute of Chemical Wood Technology of Agricultural University in Poznań are carried out investigations on

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the durability on the biological corrosion of modified wood with various synthetics resins. The said investigations are executed as well in laboratory as in natural conditions with soil contact and in sea water [5, 8, 11, 12, 14, 20]. Till to this time obtained results of field tests indicate that the material composite wood – polystyrene shows high durability degree on the complex acting atmospheric – biological factors. Such high durability has been found for the material containing 100 - 120% of polystyrene in wood. The high consumption of this resin, at high cost is till to this time however one of drawbacks of this method of wood improvement. The presented in this work results of studies pertain durability on the action of various fungi for birch and alder wood containing polystyrene in quantities from 60 - 88%. The are included further till to this time unpublished results of field tests obtained after 14 years. Sooner obtained results were presented on specialists meetings and scientific conferences.

INVESTIGATED MATERIALS

LABORATORY TESTS

The used materials in laboratory tests has been birch (*Betula* sp.) and black alder (*Alnus glutinosa* Gaertn.) wood, and material composites from wood of said species and polystyrene. Wood-polystyrene composites were in the Chair of Hydrothermal Processing and Modification of Wood of Agricultural University in Poznań, accordingly to the technology patented in PRL N° 81908 Patent [15]. The polystyrene content in wood was from 62-88%. Tests samples of dimmensions $9 \times 9 \times 120$ mm were cut from squares of properly bigger dimmensions, enabling obtaining from each square 16 samples. There were cut also proper number of twin-samples from the vincinity of control samples of all monomers. All samples from each species of wood were divided into following groups:

I – natural wood
- 1 group – samples unexposed for fungal action
- 2 group – samples exposed for fungal action

II, III – composites from birch and alder wood
- 1 group – samples unexposed for fungal action
- 2 group – samples exposed for fungal action.

All samples have been conditioned (14 days in laboratory conditions, 10 days drying to constant mass in temperature 55-60°C and air pressure about 100 Pa) and then weighted. Afterwards they were left in laboratory conditions for 4 weeks.

FIELD TESTED

The description of samples preparation for fields tests has been presented in previously published materials [6, 7, 13].

METHODS OF RESEARCH

LABORATORY TESTS

The prepared samples have been put in sterile conditions to the Kole'flasks with or malt-agar substrate (for the fungi of *Basidiomycotina* Class) or with substrate accordingly to Czapek-Dox) for *Asco-* and *Deuteromycotina*).

Samples from group "1" were placed in flasks on the sterile substrates, and of "2" group on cultivated on them mycelium of proper test fungi. The names of those fungi are given of Fig. 1, 2 and 3. Flasks with the samples were stored in conditions depending from needs of fungi groups, that is in case of *Basidiomycotina* air temperature was 22±2°C and relative humidity 80±5% while for *Asco-* and *Deuteromycotina* air temperature was 28±1°C and relative humidity of air about 95%. The time of storage of flasks with samples in such conditions was 8 weeks. After that time has been observed the speed of mycelium growth on tested materials. Then the samples were cleaned, weighted, sterilized in temperature 65°C and put to the equilibrium moisure content in air with relative humidity 98 – 100%. Then the static bending strength has been measured of all samples (the supports span 100 mm, speed of loading 5 mm/min, direction of loading parallel to the growth rings of wood). After rupture samples were dried to the constant mass and weighted in aim to determine their moisure content and weight losses after mycological tests were concluded. The number of samples in each group was 16 pieces. Results of tests were presented on the Figg. 1 and 2. The bending strenght of samples exposed for fungal action in Kolle flasks (group "2") is given on the drawings percentage of control samples strenght (group "1") stored in sterile conditions were sterile substrates.

FIELD TEST

Detailed description of samples preparation for field tests, conditions and method of conducting the tests has been presented in previous publications and reports [6, 7, 12, 23]. In the presented paper will be inculded results of investigation and observation made after 14 years from the moment of their starting up, covering alder wood (*Alnus glutinosa* (L.) Gaertn.), beech (*Fagus silvatica* L.) and pine sapwood (*Pinsu silvestris* L.) and composites obtained of them and polysrene. Content of this polymer in wood was 100-120%. Results were presented in Table 1.

RESULTS OF INVESTIGATIONS

LABORATORY TESTS

In course of laboratory tests it was found that there exist diversified speed of covering of samples with mycelium, in dependence upon tested material and species of test fungus. Distinct slowing of growth of mycelium of Coriolus versicolor in comparison with natural wood occured in case of composites wood – polystyrene. Also the appearance of this mycelium on the samples of tested composites was different from mycelium on the samples of tested composites was different from mycelium covering natural birch and alder

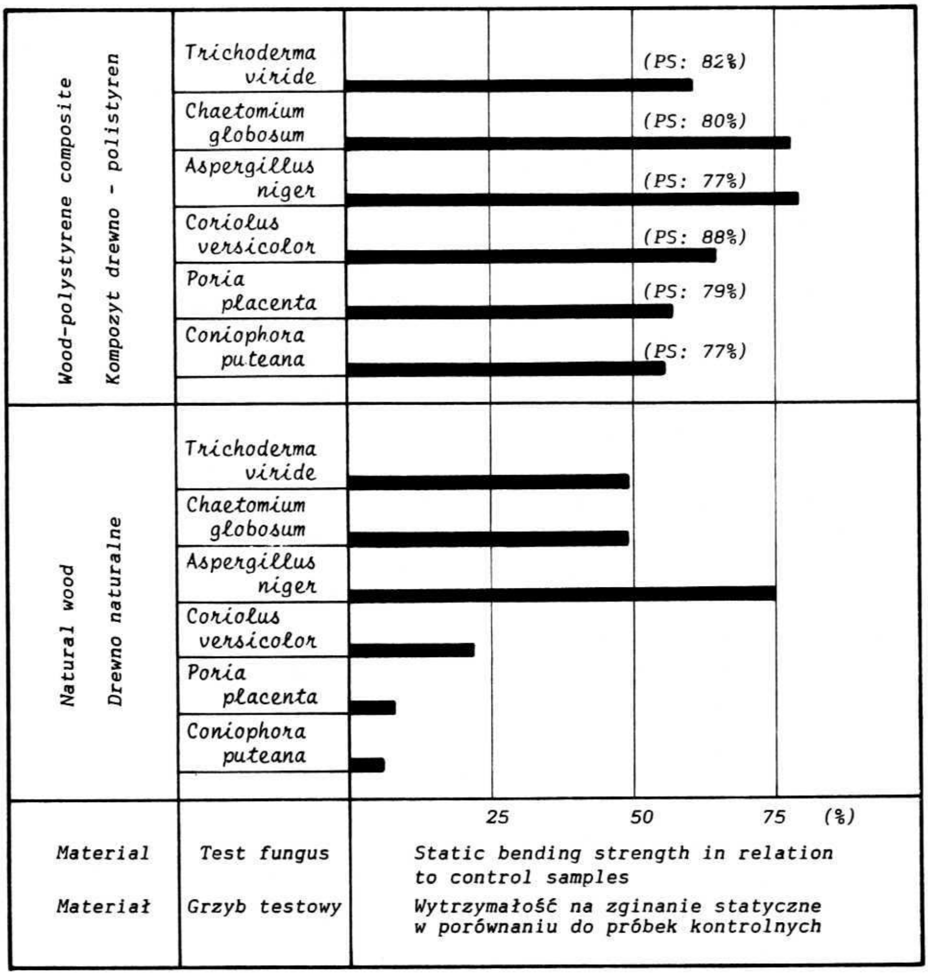

Fig. 1. Effect of fungi upon the static bending strenght of birch wood and its composite with polystyrene (PS)

Rys. 1. Wpływ grzybów na wytrzymałość na zginanie statyczne drewna brzozy i jego kompozytu z polistyrenem (PS)

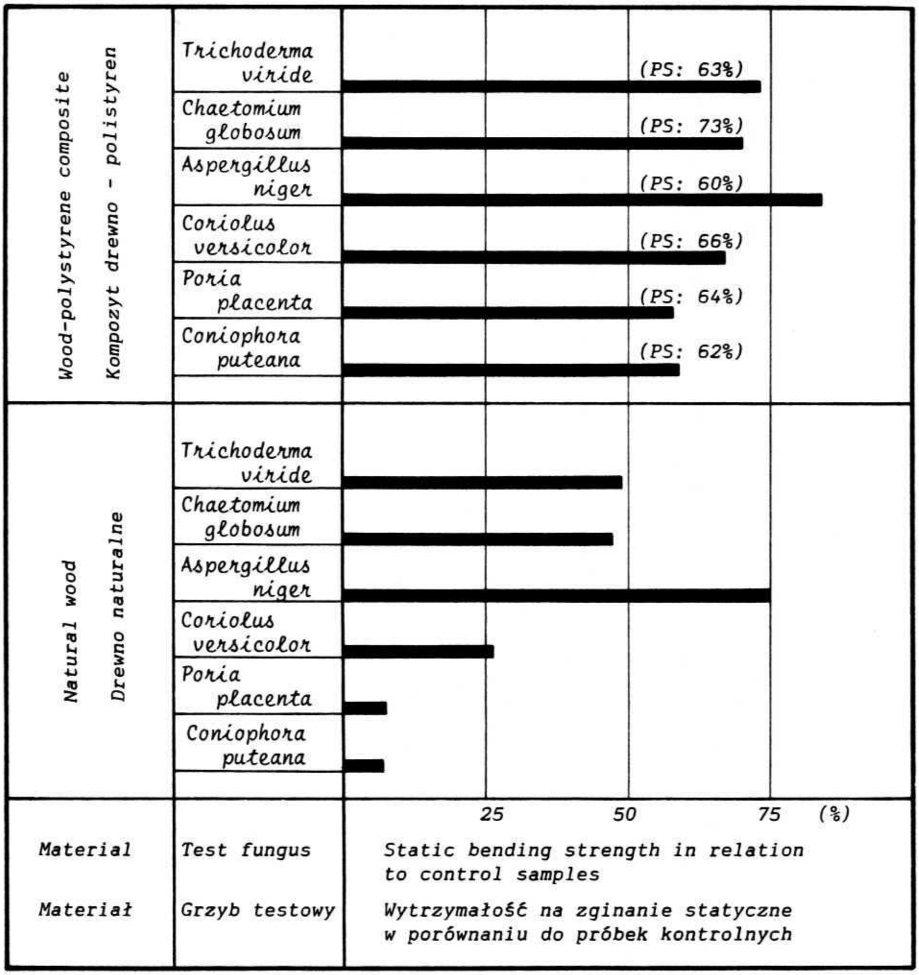

Fig. 2. Effect of fungi upon the static bending strength of alder wood and its composite with polystyrene (PS)

Rys. 2. Wpływ grzybów na wytrzymałość na zginanie statyczne drewna olchy i jego kompozytu z polistyrenem (PS)

wood. In case of soft rot fungi and moulds occurence it was observed occurence of sporulation and fruit bodies on the natural wood with slightly visible surface mycelium. On the samples of both composites mycelium occured in from of distincly developed bloom at the and of 8- week testing period. It can testify about impeded acces of hyphae of mycelium inside wood, filled in great degree with polystyrene.

The moisture content of natural wood of 8 weeks of tests overreached fibre saturation point. It can be assumed as proof of existence in flasks favourable for fungi development conditions. Above twice lower moisture content of tested in the some conditions composites wood – polystyrene certifies about distinct effect of hydrophobization, caused by the presence in wood in average about 75% of polystyrene.

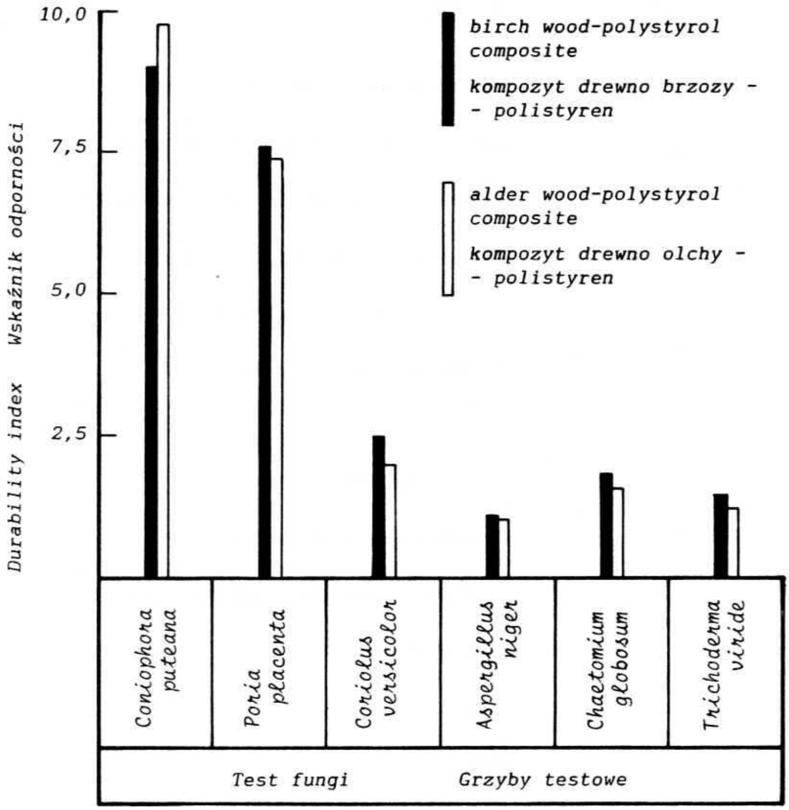

Fig. 3 Relative resistance index of wood-polystyrene composites
Rys. 3. Wskaźnik względnej odporności kompozytów drewno – polistyren na działanie grzybów

Visible differences occured in the changes of static bending strenght of wood exposed for various fungi. The greatest drops of this strength property was evoked by brown and white rot fungi. About 50% lower strength has been observed also for wood exposed on the *Chaetomium globosum* and *Trichoderma viride* activity for those fungi mass losses reached only 2.4%. *Aspergillus niger*, fungus from *Ascomycetina* is known as widely occuring species in nature is developing on various materials, causing phenomenon known as "moulds apperance" [4]. Its cellulolytic activity in lignified tissues is not great. But carried out investigations are showing, that with slight, statistically insignificant quantitative changes, this species can be the cause of arising qualitative changes of wood cell wall. It is manifested by distinct statistically certified changes of statistic bending strenght of wood samples of small dimmension of cross-section area. The qualitative changes of wood substance probably occur with greater intensity on the samples surface [10, 19], therefore drop of static bending strength is more distinct from mass losses. The fact of changes occurence in cell wall structure of outside zones of wood covered by *Asco-* and *Deuteromycotina* has been observed by numerous authors [21, 24].

Polystyrene in birch and alder wood in quantitis from 60-88% has contributed to the increase of durability of tested composites upon fungi action. Taking into account adopted in tests of preservatives on wood strenght evaluation criterion (PN-76/C-04906), this increase is insufficient to take the tested composites wood – polystyrene as durable for biological corrosion. In all cases with the exception of composite birch wood – polystyrene exposed on the action of *Aspergillus niger*, the decrease of static bending strenght of samples after 8 weeks exposition has been higher than 20%, with statistically certified significant differences.

For the possible wide evaluation of durability upon fungal action on the tested composites, the relative durability W_o has been stated. For this purpose the percentage ratio has been established of strength of given composite to the natural wood strength, taking into account the test fungus species. The numerical value of relative durability is:

$$W_o = \frac{100 - \text{decrease of composite strength}}{100 - \text{decrease of natural wood strength}}$$

On the Fig. 3 there is presented graphically relative durability of tested materials on the action of particular fungi. As it can be seen, the greatest effect of the durability increase upon the action of fungi has been found for the species causing brown rot of wood (*Coniophora puteana* and *Poria placenta*). It concerns as well composite obtained from birch wood as from alder with polystyrene. Considerably lower effect occured for the white rot fungus (*Coriolus versicolor*) as for three species causing soft rot and moulds occurence. The lowest value of durability index have both composites in respect to *Aspergillus niger*. The differences in static bending strength among natural wood and composite wood polystyrene did not go over 10%, but with lowering of it greater than 20%.

FIELD TESTS

In the research on the durability in natural conditions with the contact with soil, two criteria of evaluation of this durability were adopted. On of them that is visual classification [23], the second testing of strength with nondestructive method [18]. In both cases the durability of tested materials was stated expressed in years. In the table 1 results of those investigations are presented. Samples of pine sapwood after 3.5 years of action of atmospheric – soil conditions were practically desstrouyed. Similarly low natural durability of pine wood in contact with soil have been found in Scandinvia [1]. In the some conditions birch wood, alder and beech wood sustained only one year. Samples of composite from pine, beach and alder wood with polystyrene with content of this last in wood in the ranges 100 to 120% were not decayed under the action of complex changeable atmospheric and soil conditions. In the period over 12 years there have not been observed symptoms of biological destruction of tested materials. There did not occurt breaking of samples when loaded with

Tabela 1

Durability of scots pine, beech and alder wood and their composites with polystyrene in natural conditions in ground contact on the test field „Kamińsko"

Trwałość drewna sosny, buka i olchy oraz ich kompozytów z polistyrenem w warunkach naturalnych w kontakcie z ziemą na poligonie doświadczalnym „Kamińsko"

Material Materiał	Durability (years) Trwałość (lata)
Natural wood	
Drewno naturalne	
scots pine	
biel sosny	3,5
beech	
buk	1
alder	
olcha	1
Wood – polystyrol composite	
Kompozyt drewno – polistyren	
scot pine	
biel sosny	12
beech	
buk	12
alder	
olcha	14

force of about 20% destructive force in the bending test. Underground parts of samples were in full sound, without decay symptoms.

In the above ground parts of samples deep checks occured in the planes of radial rays. It means, that the tested wood – polystyrene composite at high content of polymer are characterized by high degree of durability in natural conditions with the contact with soil.

REASSUMPTION

Till to this time published data are showing that impregnation of wood with various synthetic resins contributes to in general distinct increase of durability upon biological corrosion. It depends, however to the some degree, from the kind of used resin and above all from its quality in wood. The bioprotective action of those substances depends mainly from limiting affiliation of wood tissue towards water and for blocking the acces of mycelium to the wood [17, 20].

In the laboratory tests wood – polystyrene composite in majority of cases has been easily covered by surface mycelium. This material in the same conditions had shown small mass losses under the action of various test fungi. Omitting other changes can be on this base taken as material durable upon biological corrosion. A it was found, in case of about 80% content of polystyrene in wood, fungi of various species are causing decrease of static bending strength of composite. It is connected probably with biological decay of cell walls of outside layers of sample, to which mycelium hyphae have eaisier access.

It is so, despite to fond of partial linking on the chemical way of polystyrene with the constituents of cell – wall of wood [16]. In respect to the fungi which are causing occurence of moulds on the various materials (e.g. *Aspergillus niger*) it can be assumed, that similarly as in soft rot where occurs damage of middle lamella the weakening of mechanical strength of composite and natural wood takes place accordingly to the close pattern. The low cellulolytic activity, distinct decay of hemicelluloses [24] under influence of those fungi are speaking for such interpretation of obtained result. Occuring on the surface of samples qualitative changes are contributing to the distinct drops of static bending strength of samples [25]. About deciding influence of quantity of polystyrene in wood, on the composite durability upon biological corrosion are informing results of 14 years of investigations in field conditions in the contact with soil.

This composite containing 100-120% of polystyrene sustained 14 years without changes of mechanical strength. Mentioned previously checks and delaminations of above ground parts of samples were probably caused by frequent changes of moisture and photooxydative reactions [10]. It can not be excluded in this case also partial depolymerization of polystyrene in composite. Obtainig from wood and polystyrene the in full biodurable material at lower synthetic resin content is possible by the addition to it toxic substance. Such possibility has been found on the laboratory scale, on the example of pentachlorophenol and one of its derivative [5].

But sanitary – toxicological – ecological reasons need however, that for this purpouse is to be used fungicide of newer generation of decidedly lower toxicity.

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REFERENCES

1. Borsholt E.: NWPC filed test No. 1 with wood preservatives. Results after 10 years testing. Nordic Wood Preserv. Council., NWPC-INF. No 9, 1979, ss. 18.
2. Burmester A.: Holz, Kunstoff und Gammastrahlung. Holz-Zbl., 1964, 90, s. 1989-1990.
3. Czajnik M.: Z badań nad zastosowaniem żywic syntetycznych do konserwacji drewna porażonego przez grzyby. Zesz. Nauk. SGGW Warszawa, 1970, s. 191-204.
4. Fasiatova O.: Plísne a vlákinité houby v technické mikrobiologii. Nakl. Techn. Literat., Praha 1979, ss. 256.

5. Gajdziński M., Lutomski K.: Odporność na korozję biologiczną drewna zmodyfikowanego styrenem z dodatkiem składników grzybobójczych. Zesz. Probl. Post. Nauk Roln., 1980, z. 231, s. 103-113.
6. Gajdziński M., Lutomski K.: Badania nad trwałością lignomeru eksploatowanego na przestrzeni otwartej w kontakcie z ziemią. Zesz. Probl. Post. Nauk Roln., 1983, z. 260, s. 212-228.
7. Gajdziński M., Lutomski K.: Trwałość drewna ulepszonego polistyrenem, wystawionego na działanie zmiennych warunków klimatyczno-glebowych. Mater. VI Sympozjum „Modyfikacja drewna'87". PAN/AR w Poznaniu, 1987, s. 178-184.
8. Gambetta A., Orlandi E.: Investigations on the resistance of modified wood to biological attack. Fol. Forest. Polon., Ser. B, 1989, z. 20, s. 13-28.
9. Ivanov N.I., Panfilova V.A., Zajvij V.A.: K vaprosu ispolzovanija mechanitscheskich charakterisik pri ocenkie biostoikosti modificirovanoj drevesiny. Svojstva dreviesiny, jejo zaschtschita i drevesnyje materialy. Krasnojarsk, 1968, s. 104-107.
10. Kühne H., Leukens U., Sell W., Wälchli O.: Freiland-Bewitterungsversuche am Holz und Aussenanstrichen für Holz. Eidg. Mater.-u. Versuchsanst. Dübendorf – St. Gallen, 1972, Ber. Nr. 198, ss. 51.
11. Lutomski K.: Resistance of beech wood modified with styrene, methyl methacrylate and disosyanate against the action of fungi. Mater. u. Organ., 1975, 10 (4) s. 255-262.
12. Lutomski K. (1986): Stoikost drevesiny modificirovannoj smjesju vinilovoj i melaminovoj smoly na diejstwije gribov iz klassov Asco-, Deutero-, i Basidiomycetes. Mater. Konfer. „Zwiększanie trwałości drewna" Plovdiv, 1986.
13. Lutomski K.: Three years of field tests with „Lignomer" stakes in ground contact. Mater. 12th Annual Meeting Int. Res. Group on Wood Preserv. 1981, Doc. No: IRG/WP/3166.
14. Lutomski K., Ławniczak M.: Z badań nad odpornością drewna modyfikowanego na działanie grzybów. Zesz. Nauk. SGGW – Leśnictwo 18, 1972, s. 99-115.
15. Ławniczak M.: Sposób polimeryzacji monomerów w drewnie. Patent PRL Nr 81908, 1971.
16. Ławniczak M., Melcerowa A., Melcer I.: Analytische Charakterisierung von Polymerholz der Kiefer und Erle. Holzforschung und Holzverwertung. 1987, R. 39, nr 5, s. 119-121.
17. Morgós A., Czvikovszky T.: Composite materials on the basis of wood and silicon acrylates. Fol. Forest. Polon., Ser. B, 1989, z. 20, s. 5-11.
18. Paserin V.: Zastosowanie metody nieniszczącej w poligonowych badaniach właściwości grzybobójczych środków ochrony drewna. Zesz. Probl. Post. Nauk Roln., 1976, z. 178, s. 63-73.
19. Seifert K.: Die chemische Veränderung der Buchenholz-Zellwand durch Moderfäule (*Chaetomium globosum* Kunze). Holz als Roh- u. Werkst. 1966, 24 (5), s. 185-189.
20. Taylor J.M.: The termite resistance of wood plastic composites. Intern. Biodet. Bull., 1973, 3, s. 76-78.
21. Ważny J.: Badania nad występowaniem „rozkładu pleśniowego" w Polsce. Zesz. Nauk. SGGW – Leśnictwo. 1970, z. 14, s. 51-71.
22. Ważny J.: Wpływ działania grzybów *Merulius lacrymans* (Wulf.) Fr. i *Coniophora cerebella* Pers. na fizyczne i mechaniczne własności niektórych gatunków drewna. Fol. Forest. Polon. Ser. B., 1959, z. 1, s. 9-81.
23. Ważny J., Lutomski K., Kundzewicz A.W.: Badania poligonowe skuteczności środków ochrony drewna Synpregnit CBZ i Pentor 70. Fol. Forest. Polon., Ser. B, 1992, z. 23, s. 111-125.
24. Wolf F., Liese W.: Zur Bedeutung von Schimmelpilzen für die Holzqualität. Holz als Roh- u. Werkst. 1977, 35-57.
25. Zyska B.: Badania nad graniczną wartością grzybobójczą fluorokrzemianów w drewnie. Prace Kom. Nauk Roln. i Kom. Nauk Leśn. PTPN, Poznań, 1963, T. XV (2), s. 147-199.
26. Zyska B.: Mikrobiologiczna korozja materiałów. Wyd. Nauk.-Techn., Warszawa, 1977, ss. 446.

KOMPOZYTY DREWNO – POLISTYREN W TESTACH ODPORNOŚCI BIOLOGICZNEJ

Streszczenie

Naturalne drewno brzozy (*Betula* sp.) i olchy czarnej (*Alnus glutinosa* (L.) Gaertn.) oraz drewno tych gatunków zawierające polistyren w ilościach od 62 do 88%, poddano w warunkach laboratoryjnych działaniu grzybów *Coniophora puteana* (Schum. ex Fr.) Karst., *Coriolus versicolor* (L. ex Fr.) Quel., *Chaetomium globosum* Kunze, *Trichoderma viride* Pers., *Paeciliomyces varioti* Bainier i *Aspergillus niger* van Thieghem. Po 8 tygodniach oznaczono ubytki masy próbek oraz zmiany wytrzymałości na zginanie statyczne w porównaniu z próbkami tych samych materiałów, nie wystawionych na działanie grzybów. Stwierdzono wyższą odporność od drewna naturalnego badanego kompozytu drewno – polistyren, jednak nie tak dużą, aby uznać go za w pełni odporny na korozję biologiczną.

Wyniki 14-letnich badań prowadzonych na przestrzeni otwartej w kontakcie z ziemią nad naturalnym drewnem sosny (*Pinus silvestris* L.), buka (*Fagus silvatica* L.) i olchy czarnej oraz drewnem tych gatunków zawierającym ponad 100% polistyrenu wykazały, że kompozyt ten w porównaniu z drewnem naturalnym wyróżnia się co najmniej 14-krotnie wzrostem odporności na kompleksowo działające czynniki atmosferyczne i biologiczno-glebowe.

Z przeprowadzonych badań wynika między innymi, że o odporności na korozję biologiczną kompozytów drewno – polistyren decyduje zawartość polimeru w drewnie.

Authors address:
Prof. dr hab. Kazimierz Lutomski
Instytut Chemicznej Technologii Drewna AR
ul. Wojska Polskiego 38/42
60-637 Poznań – Poland